

SOx-NOx-Rox Box™ Flue Gas Cleanup Demonstration Project

Project completed

Participant

The Babcock & Wilcox Company

Additional Team Members

Ohio Edison Company—cofunder and host

Ohio Coal Development Office—cofunder

Electric Power Research Institute—cofunder

Norton Company—cofunder and SCR catalyst supplier

3M Company—cofunder and filter bag supplier

Owens Corning Fiberglas Corporation—cofunder and filter bag supplier

Location

Dilles Bottom, Belmont County, OH (Ohio Edison Company's R.E. Burger Plant, Unit No. 5)

Technology

The Babcock & Wilcox Company's SOx-NOx-Rox Box™ (SNRB™) process

Plant Capacity/Production

5-MWe equivalent slipstream from a 156-MWe boiler

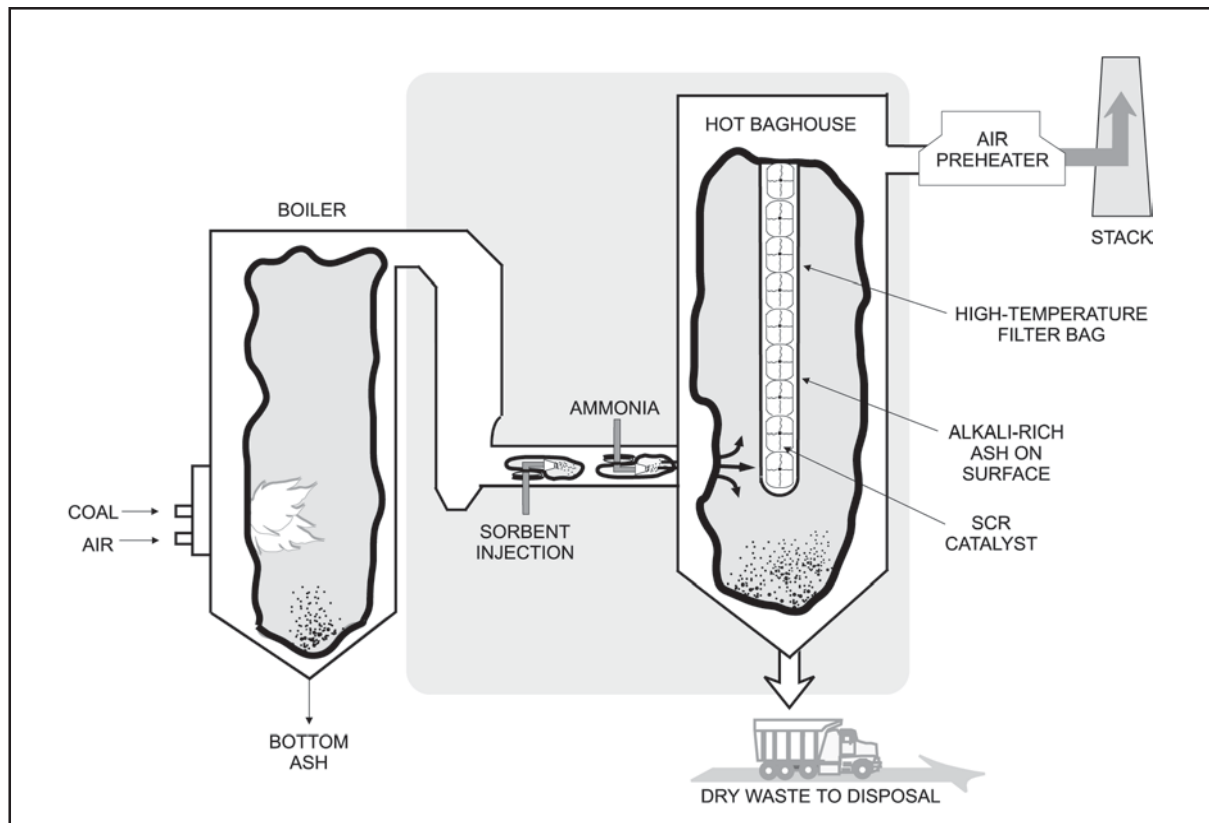
Coal

Bituminous coal blend, 3.7% sulfur average

Project Funding

Total	\$13,271,620	100%
DOE	6,078,402	46
Participant	7,193,218	54

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Project Objective

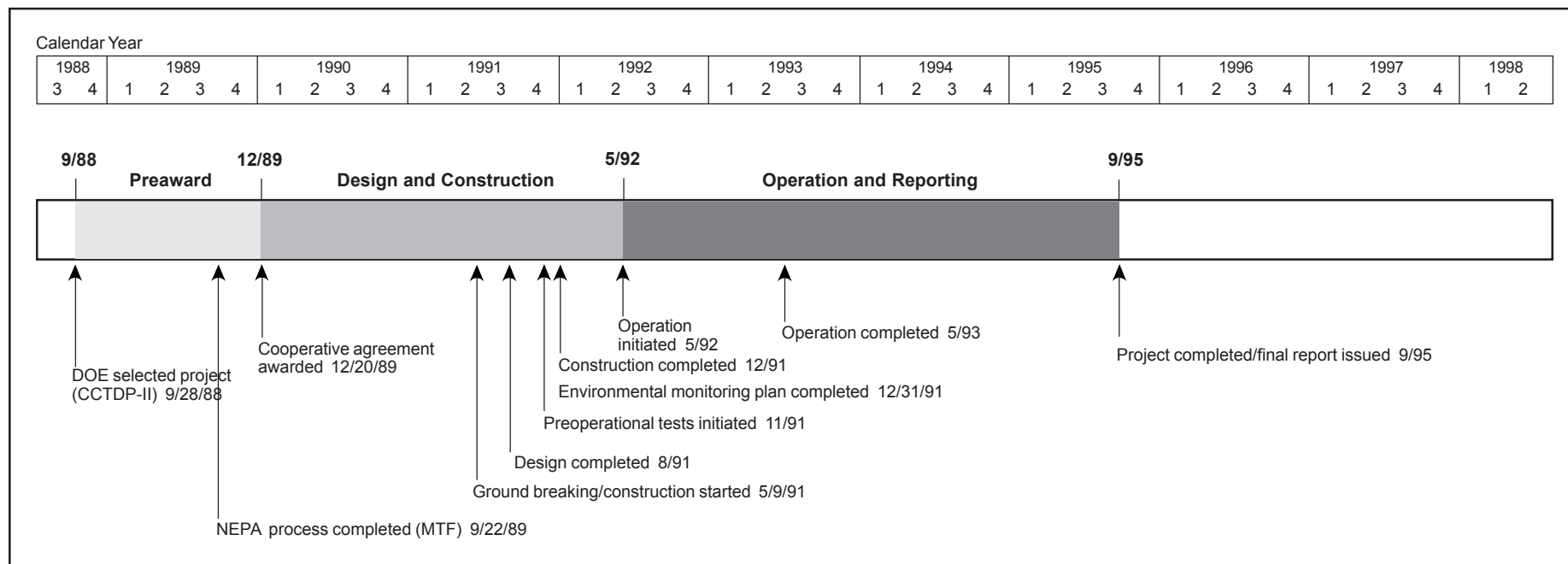
To achieve greater than 70% SO₂ removal and 90% or higher reduction in NO_x emissions while maintaining particulate emissions below 0.03 lb/10⁶ Btu.

Technology/Project Description

The SNRB™ process combines the removal of SO₂, NO_x, and particulates in one unit—a high-temperature baghouse. SO₂ removal is accomplished using either calcium- or sodium-based sorbent injected into the flue gas. The NO_x removal is accomplished by injecting ammonia (NH₃) to selectively reduce NO_x in the presence of a selective catalytic reduction (SCR) catalyst. Particulate removal is accomplished by high-temperature fiber bag filters.

The 5-MWe SNRB™ demonstration unit is large enough to demonstrate commercial-scale components while minimizing the demonstration cost. Operation at this scale

also permitted cost-effective control of the flue gas temperature, which allowed for evaluation of performance over a wide range of sorbent injection and baghouse operating temperatures. Thus, several different arrangements for potential commercial installations could be simulated.



Results Summary

Environmental

- The SO₂ removal efficiency of 80% was achieved with commercial-grade lime at a calcium-to-sulfur (Ca/S) molar ratio of 2.0 and temperature of 800–850 °F.
- The SO₂ removal efficiency of 90% was achieved with sugar-hydrated lime and lignosulfonate-hydrated lime at a Ca/S molar ratio of 2.0 and temperature of 800–850 °F.
- The SO₂ removal efficiency of 80% was achieved with sodium bicarbonate at a sodium-to-sulfur (Na₂/S) molar ratio of 1.0 and temperature of 425 °F.
- The SO₂ emissions were reduced to less than 1.2 lb/10⁶ Btu with 3–4% sulfur coal, with a Ca/S molar ratio as low as 1.5 and Na₂/S molar ratio of 1.0.
- Injection of calcium-based sorbents directly upstream of the baghouse at 825–900 °F resulted in higher overall SO₂ removal than injection further upstream at temperatures up to 1,200 °F.

- The NO_x reduction of 90% was achieved with an NH₃/NO_x molar ratio of 0.9 and temperature of 800–850 °F.
- Air toxics removal efficiency was comparable to that of an electrostatic precipitator (ESP), except that hydrogen fluoride (HF) was reduced by 84% and hydrogen chloride (HCl) by 95%.

Operational

- Calcium utilization was 40–45% for SO₂ removals of 85–90%.
- Norton Company's NC-300 zeolite SCR catalyst showed no appreciable physical degradation or change in catalyst activity over the course of the demonstration.
- No excessive wear or failures occurred with the filter bags tested: 3M's Nextel ceramic fiber filter bag and Owens Corning Fiberglas S-Glass filter bag.

Economic

- Capital cost in 1994 dollars for a 150-MWe retrofit was \$253/kW, assuming 3.5% sulfur coal, baseline NO_x emissions of 1.02 lb/10⁶ Btu, 65% capacity factor, and 85% SO₂ and 90% NO_x removal.
- Levelized cost over 15 years in constant 1994 dollars was \$553/ton of SO₂ and NO_x removed.

Project Summary

SNRB™ incorporates two successful technology development efforts that offer distinct advantages over other control technologies. High-temperature filter bags and circular monolith catalyst developments enabled multiple emission controls in a single component with a low plan-area space requirement. As a post-combustion control system, it is simple to operate. The high-temperature bag provides a clean, high-temperature environment compatible with effective SCR operation, and a surface for enhanced SO₂/sorbent contact (creates a sorbent cake on the surface).

Environmental Performance

Four different sorbents were tested for SO₂ capture. Calcium-based sorbents included commercial grade hydrated lime, sugar-hydrated lime, and lignosulfonate-hydrated lime. In addition, sodium bicarbonate was tested. The optimal location for injecting the sorbent into the flue gas was immediately upstream of the baghouse. Essentially, the SO₂ was captured by the sorbent in the form of a filter cake on the filter bags (along with fly ash).

With the baghouse operating above 830 °F, injection of commercial-grade hydrated lime at Ca/S molar ratios of 1.8 and above resulted in SO₂ removals of over 80%. At a Ca/S molar ratio of 2.0, sugar-hydrated lime and lignosulfonate-hydrated lime increased performance by approximately 8%, for overall removal of approximately 90%. SO₂ removal of 85–90% was obtained with calcium utilization in the range of 40–45%. Injection of the calcium-based sorbents directly upstream of the baghouse at 825–900 °F resulted in higher overall SO₂ removal than injection further upstream at temperatures up to 1,200 °F.

The SO₂ removal using sodium bicarbonate was 80% at an Na₂/S molar ratio of 1.0 and 98% at an Na₂/S molar ratio of 2.0, at a significantly reduced baghouse temperature of 450–460 °F. The SO₂ emissions while burning a 3–4% sulfur coal were reduced to less than 1.2 lb/10⁶ Btu with a Ca/S molar ratio as low as 1.5 and Na₂/S molar ratio less than 1.0.

To capture NO_x, ammonia was injected between the sorbent injection point and the baghouse. The ammonia and

NO_x reacted to form nitrogen and water in the presence of Norton Company's NC-300 series zeolite SCR catalyst. With the catalyst being located inside the filter bags, it was well protected from potential particulate erosion or fouling. The sorbent reaction products, unreacted lime, and fly ash were collected on the filter bags and thus removed from the flue gas.

A NO_x emission reduction of 90% was readily achieved with ammonia slip limited to less than 5 ppm. This performance reduced NO_x emissions to less than 0.10 lb/10⁶ Btu. NO_x reduction was insensitive to temperatures over the catalyst design temperature range of 700–900 °F. Catalyst



The sorbent injection into the duct upstream of SO_x-NO_x-Rox Bag™ system.

space velocity (volumetric gas flow/catalyst volume) had a minimal effect on NO_x removal over the range evaluated.

Turndown capability for tailoring the degree of NO_x reduction by varying the rate of ammonia injection was demonstrated for a range of 50–95% NO_x reduction. No appreciable physical degradation or change in the catalyst activity was observed over the duration of the test program. The degree of oxidation of SO₂ to SO₃ over the zeolite catalyst appeared to be less than 0.5%. (SO₂ oxidation is a concern for SCR catalysts containing vanadium.) Leach potential analysis of the catalyst after completion of the field test showed that the catalyst remained nonhazardous for disposal.

Particulate emissions were consistently below NSPS standards of 0.03 lb/10⁶ Btu, with an average of 0.018 lb/10⁶ Btu, which corresponds to a collective efficiency of 99.89%. Hydrated lime injection increased the baghouse inlet particulate loading from 5.6 to 16.5 lb/10⁶ Btu. Emissions testing with and without the SCR catalyst installed revealed no apparent differences in collection efficiency. On-line cleaning with a pulse air pressure of 30–40 lb/in² was sufficient for cleaning the bag/catalyst assemblies. Typically, one of five baghouse modules in service was cleaned every 30–150 minutes.

A comprehensive air toxics emissions monitoring test was performed at the end of the SNRB™ demonstration test program. The targeted emissions monitored included trace metals, volatile organic compounds, semi-volatile organic compounds, aldehydes, halides, and radionuclides. These species were a subset of the 189 hazardous substances identified in the CAAA. Measurements of mercury speciation, dioxins, and furans were unique features of this test program. The emissions control efficiencies achieved for various air toxics by the SNRB™ system were generally comparable to those of the conventional ESP at the power plant. However, the SNRB™ system did reduce HCl by an average of 95% and HF emissions by an average of 84%, whereas the ESP had no effect on these constituents.

Operation of the SNRB™ demonstration resulted in the production of approximately 830 tons of fly ash and by-product solids. An evaluation of potential uses for the by-product showed that the material might be used for

agricultural liming (if pelletized). Also, the solids potentially could be used as a partial cement replacement to lower the cost of concrete.

Operational Performance

A 3,800-hour durability test of three fabric filters was completed at the Filter Fabric Development Test Facility in Colorado Springs, Colorado in December 1992. No signs of failure were observed. All of the demonstration tests were conducted using the 3M Company Nextel ceramic fiber filter bags or the Owens Corning Fiberglas S-Glass filter bags. No excessive wear or failures occurred in over 2,000 hours of elevated temperature operation.

Economic Performance

For a 150-MWe boiler fired with 3.5% sulfur coal and NO_x emissions of 1.02 lb/10⁶ Btu, 65% capacity factor, and 85% SO_2 and 90% NO_x removal, the projected capital cost of a SNRBTM system is approximately \$253/kW (1994\$), including various technology and project contingency factors. A combination of fabric filter, SCR, and wet scrubber for achieving comparable emissions control has been estimated at \$360–400/kW. Variable operating costs are dominated by the cost of the SO_2 sorbent for a system designed for 85–90% SO_2 removal. Fixed operating costs primarily consist of system operating labor and projected labor and material for the hot baghouse and ash-handling systems. Levelized costs over 15 years in constant 1994 dollars are estimated at \$553/ton of SO_2 and NO_x removed.

Commercial Applications

Commercialization of the technology is expected to develop with an initial application equivalent to 50–100 MWe. The focus of marketing efforts is being tailored to match the specific needs of potential industrial, utility, and independent power producers for both retrofit and new plant construction. SNRBTM is a flexible technology that can be tailored to maximize control of SO_2 , NO_x , or combined emissions to meet current performance requirements while providing flexibility to address future needs.

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Workers lower one of the catalyst holder tubes into a mounting plate in the penthouse of the high-temperature baghouse.